

Motivation for a MAPS tracker in sPHENIX

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What do we need from tracking?

The main legs of the sPHENIX physics program are:

- Jets
- Heavy flavor tagged jets
- Upsilon

Upsilon are the principal momentum resolution driver (below 10 GeV/c):

- Require 100 MeV mass resolution at $M = 10 \text{ GeV}/c^2$
- Needs $\Delta p_T / p_T \sim 1.2\%$ for 1-10 GeV/c

B-tagged jets drive displaced vertex requirements (both resolution & efficiency):

- Semileptonic decay - requires excellent DCA resolution
- Multiple large DCA tracks - requires excellent efficiency
- Secondary vertex mass - requires excellent DCA resolution

Jet substructure drives the requirement for low fake rates:

Requires that fairly high momentum tracks be identified with good efficiency in a **very** high track density environment

Tracking options

The tracking options that have been considered for sPHENIX are:

Reused PHENIX pixels		Silicon strip outer tracker
OR	+	OR
MAPS based pixels		TPC outer tracker
		OR
		MAPS based outer tracker

Inner Silicon

The proposal to reconfigure the PHENIX pixel detectors as a 2-layer inner tracker in sPHENIX does not look promising. They were not designed to do what sPHENIX needs

The detector has worked well enough in PHENIX to enable successful B and D separation in Au+Au collisions using semi-leptonic decays

However it suffers from large dead areas that make it unsuitable for measurements that require displaced vertex measurements with high efficiency. This can probably not be fixed well enough when reconfiguring it for sPHENIX.

The B-tagged jet program would probably not be feasible with it.

We are still looking at it, but in my opinion, we will **have** to go to a MAPS based inner tracker to be able to pull off any reasonable heavy flavor tagged jet program in sPHENIX.

MAPS inner silicon detector

A three layer MAPS detector similar to the ALICE ITS upgrade inner barrel would be ideal as the sPHENIX inner tracker.

It would provide:

- Excellent pattern recognition
- Excellent DCA resolution
- Excellent track efficiency (assuming high live fraction)

The combination of excellent DCA resolution with excellent efficiency would enable B-jet tagging by all three of the proposed techniques mentioned earlier.

And it would greatly aid in track pattern recognition because it would provide very precise hit coordinates in both Φ and z

Outer tracker

We have considered a silicon strip tracker and a TPC for the outer tracker.

The TPC would have better momentum resolution at low momentum than any silicon tracker because of its low mass - at least at low rates.

It is going to require a lot of study before we know if a TPC will work in the rate environment of Au+Au collisions in sPHENIX.

The silicon strip tracker as presently pictured would require ganging together of up to 6 tracking strips in the readout. Combined with the length of the strips in z, this produces significant issues with pattern recognition - the fake track rates are quite high.

A MAPS outer tracker would not suffer from pattern recognition problems, and the low mass per layer would allow us to make the outer layer radius smaller than for the strip tracker.

Complete MAPS tracker

We have some simulations in simplified cylinder cell geometry of the performance of the silicon options. For the MAPS case these simulations assume average thicknesses of:

Inner three layers: 0.3% / layer

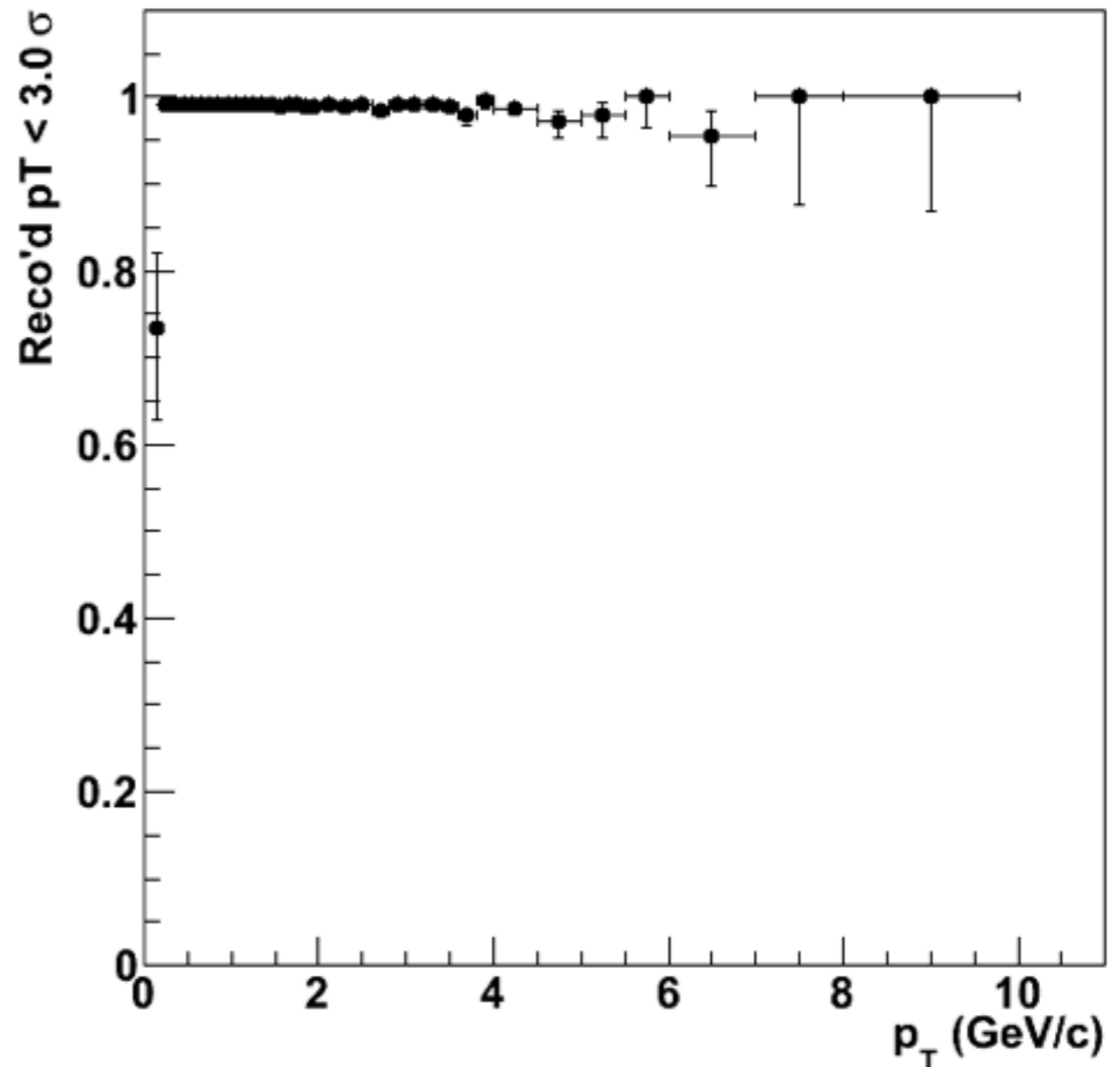
Outer four layers: 0.8% / layer

Mike is working on importing a realistic geometry into our GEANT 4 simulation of sPHENIX.

The biggest advantage of a MAPS outer tracker

Pattern recognition. Reconstructed tracks within 3σ of truth momentum

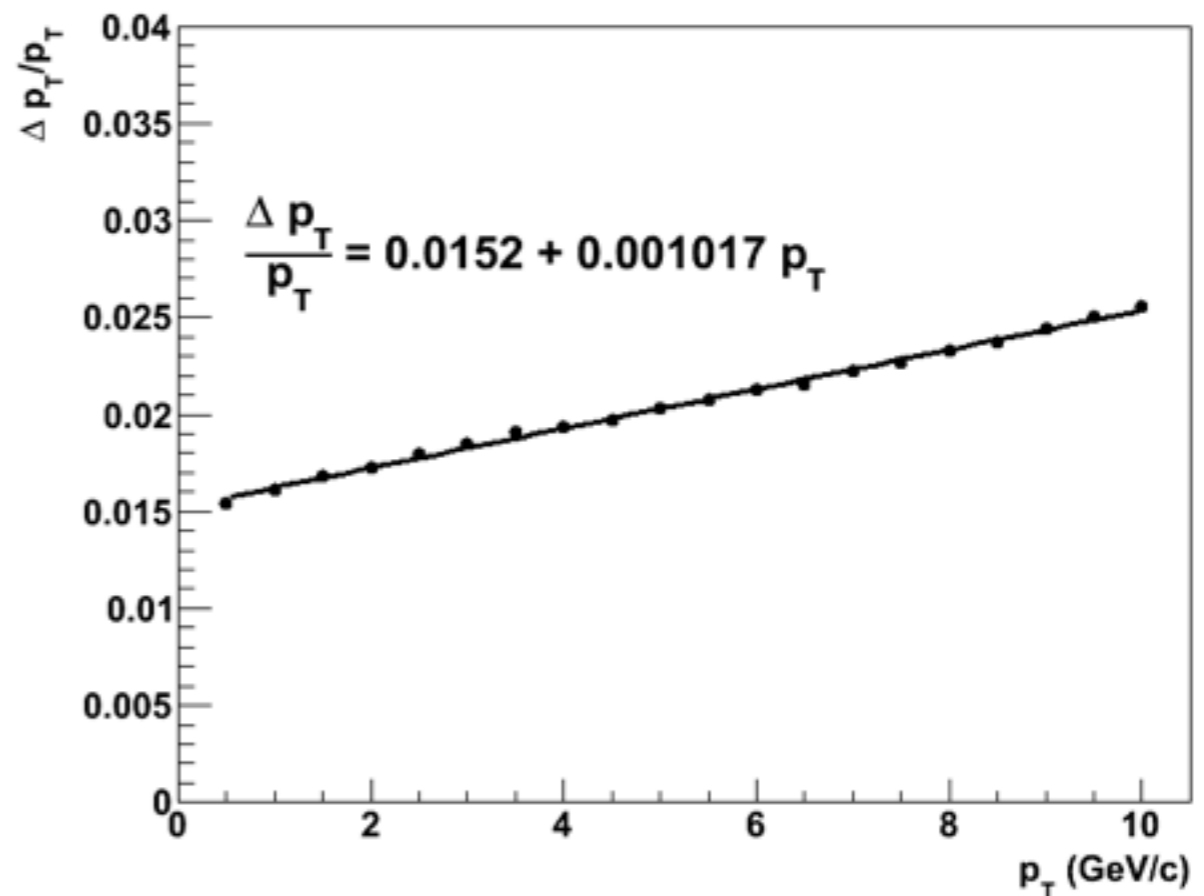
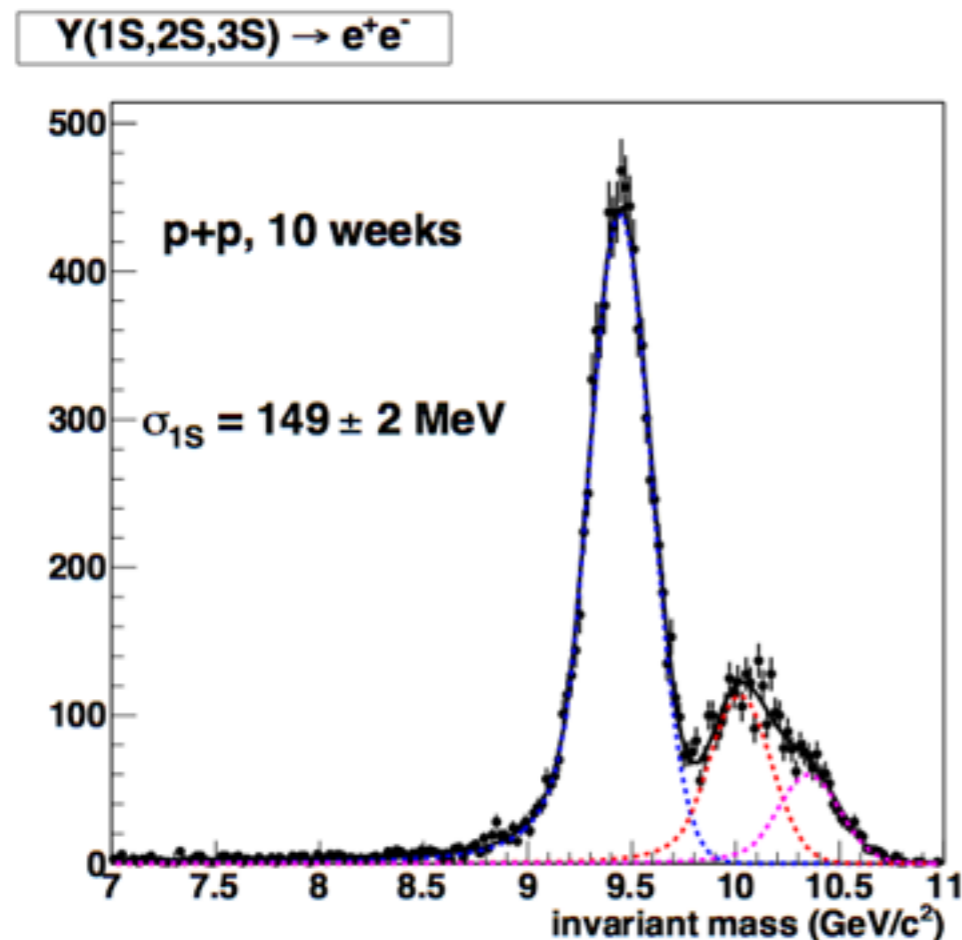
30x30 and 50x50 micron pixel size



What would we get from a MAPS outer tracker?

The momentum resolution in the range of interest for the Upsilon program is multiple scattering limited for any silicon detector.

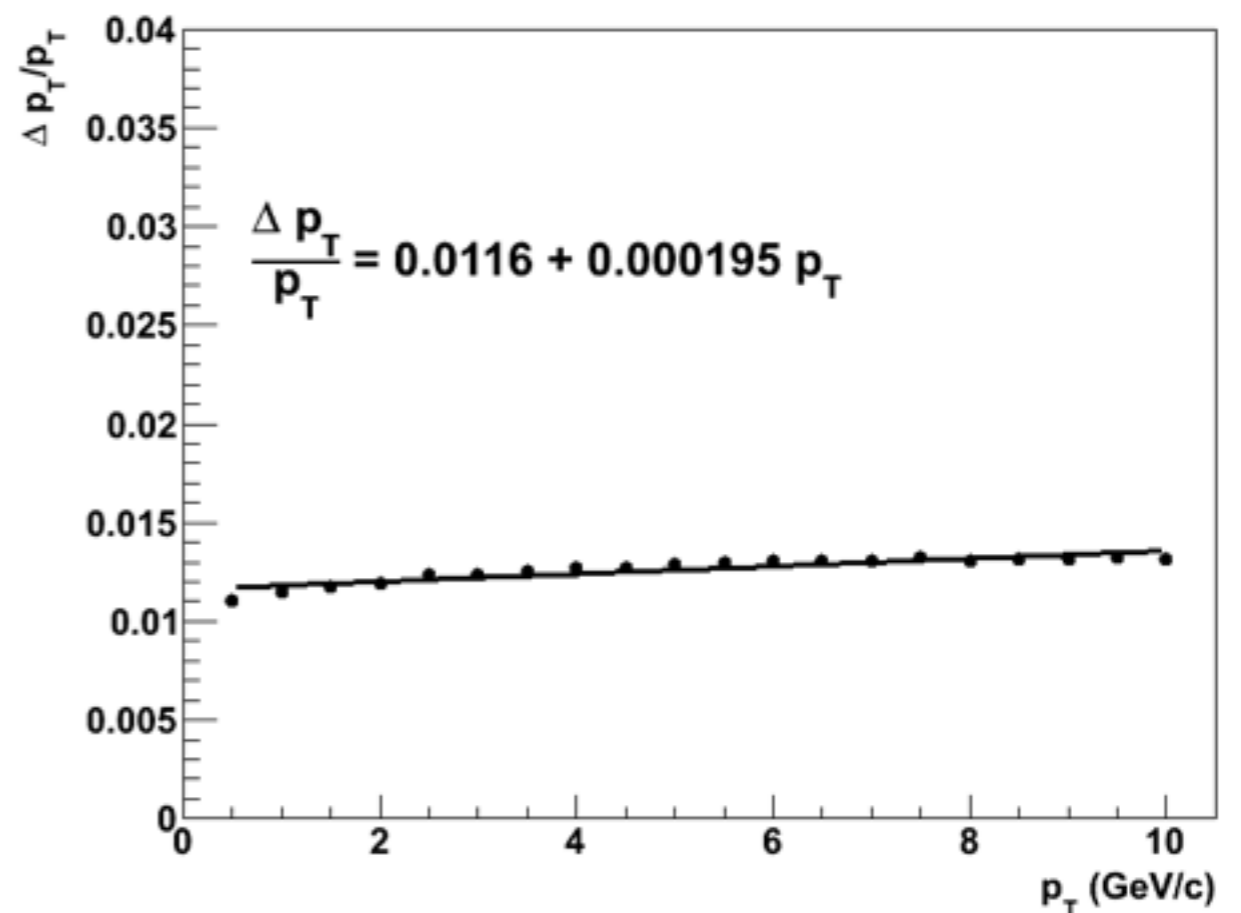
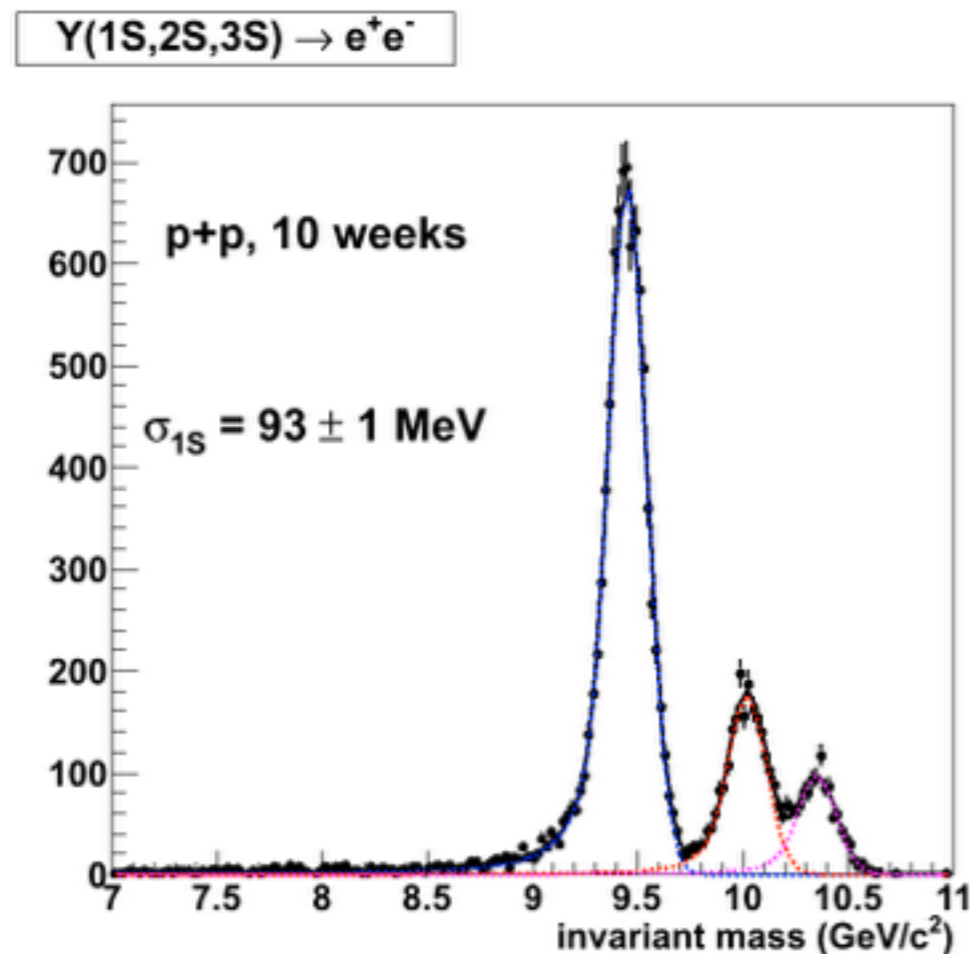
The momentum resolution is primarily determined by the outer radius of the tracker. This plot shows the momentum resolution and Upsilon mass resolution for a MAPS tracker with pixel size 20x20 μm with the **outer layer at 40 cm**. The pixel size is not critical here.



What would we get from a MAPS outer tracker?

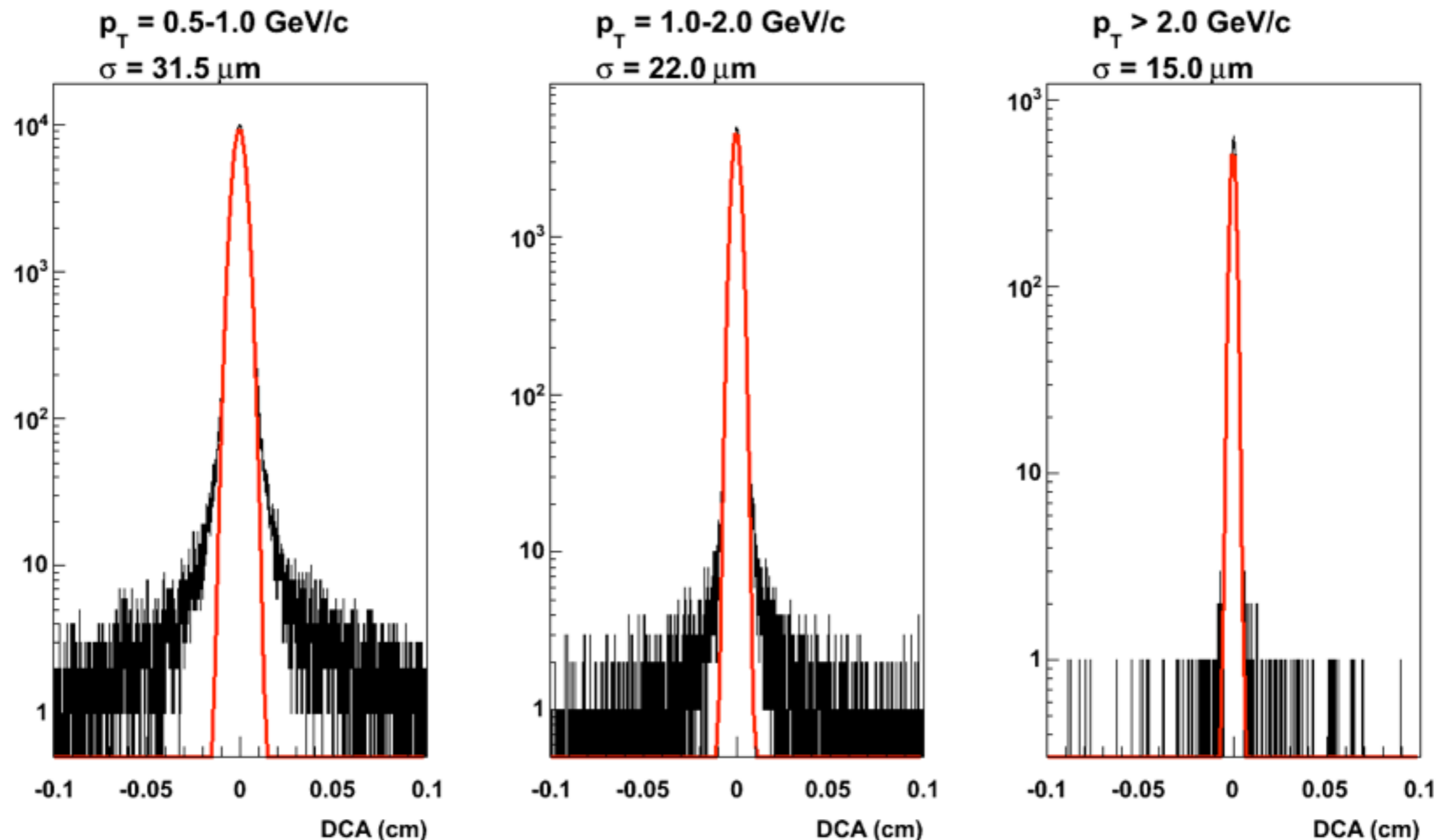
The momentum resolution in the range of interest for the Upsilon program is multiple scattering limited for any silicon detector.

The momentum resolution is primarily determined by the outer radius of the tracker. This plot shows the momentum resolution and Upsilon mass resolution for a MAPS tracker with pixel size $20 \times 20 \mu\text{m}$ with the **outer layer at 60 cm**. The pixel size is not critical here.



What would we get from a MAPS outer tracker?

This plot shows the DCA resolution for a MAPS tracker with pixel size $20 \times 20 \mu\text{m}$ with the **outer layer at 60 cm**. These are from central HIJING events.



Backup

Tracking performance criteria

We have recently decided to adopt a set of criteria for tracking performance that can be applied to all combinations of our 4 tracking detector options - **in progress**

Physics Channel	Physics requirements	Momentum resolution	DCA resolution	eID h rejection	Single track off.	Fake track rate
Y-> ee	$\Delta M = 100 \text{ MeV}$ $A\varepsilon = 50\%$ of geom. acceptance	$\Delta p_T < 1.2\%$ (1-8 GeV/c)	N/A	> 90	90% (>2 GeV/c) ?	x% (before CEMC) y% (after CEMC)
D'(z)/D(z)	$\sigma^h/\sigma^{\text{jet}} = x\%$ z = 0-0.8	$\Delta p_T < 4\%$ (1-40 GeV/c)	N/A	N/A ?	x% high pT y% low pT	x% within jet y% overall
b-jet ID via track counting	35% purity at 45% efficiency	?	< 70 μm	N/A	x% (set by 35% @ 45% goal)	y% (set by 35% @ 45% goal)
b-jet ID via secondary vertex	35% purity at 45% efficiency	?	< 70 $\mu\text{m}/(2-3?)$	N/A	90% (>2 GeV/c) ?	y% overall
$\gamma+h$ jet + h	h p_T below jet reco threshold	?	N/A	N/A	90% (>2 GeV/c) ?	y% overall pT dependent
Particle flow jets	?	?	N/A	N/A	90% (>2 GeV/c) ?	y% overall pT dependent